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Can agricultural credit scoring for microfinance institutions be implemented and improved by weather data?

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Abstract

Purpose: In recent years, the application of credit scoring in urban microfinance institutions became popular, while rural microfinance institutions, which mainly lend to agricultural clients, are hesitating to adopt credit scoring. The present study aims to explore whether microfinance credit scoring models are suitable for agricultural clients, and if such models can be improved for agricultural clients by accounting for precipitation.

Design/Methodology/Approach: This study merges two data sets: (i) 24,219 loan and client observations provided by the AccèsBanque Madagascar and (ii) daily precipitation data made available by CelsiusPro. An in- and out-of-sample splitting separates model building from model testing. Logistic regression is employed for the scoring models.

Findings: The credit scoring models perform equally well for agricultural and non-agricultural clients. Hence, credit scoring can be applied to the agricultural sector in microfinance. However, the prediction accuracy does not increase with the inclusion of precipitation in the agricultural model. Therefore, simple correlation analysis between weather events and loan repayment is insufficient for forecasting future repayment behavior.

Research Limitation/Implication: The results should be verified in different countries and climate contexts to enhance the robustness.

Social Implication: By applying scoring models to agricultural clients as well, all clients can benefit from an improved risk assessment (e.g. faster decision-making).

Originality/Value: To the best of our knowledge, this is the first study investigating the potential of microfinance credit scoring for agricultural clients in general and for Madagascar in particular. Furthermore, this is the first study that incorporates a weather variable into a scoring model.

Keywords: Microfinance, Credit scoring, Agricultural credit, Precipitation

1. Introduction

The competition in urban microfinance sectors is high, and various microfinance institutions (MFIs) are often vying for the same clients (Caudill et al., 2009). This high level of competition forces MFIs into utilizing more cost-saving behaviors (Copestake, 2007). In this context, the risk evaluation process of loan applicants is becoming the focus of lenders (Prior and Argandoña, 2009). Compared to conventional banking, which relies mainly on collateral and business documentation, the cash-flow based approach of microfinance requires verification of client information prior to loan disbursement, which is time-consuming and thus costly (Armendáriz and Morduch, 2000).

In order to decrease evaluation costs, MFIs introduced credit scoring (Bumacov et al., 2014). Credit scoring is a statistical method used to forecast the risk of a single client.[1] Thereby, a link between certain loan applicant characteristics and loan repayment behavior is established. This information is later used to predict the potential occurrence of a pre-defined event, such as a loan default, based on the characteristics of a new loan applicant (Schreiner, 2004). Once the probability of a loan default is estimated, clients are assigned to a certain risk category. In this way, credit scoring has the potential to lower operational costs by assisting loan officers in decision-making (Bumacov et al., 2014; de Cnudde et al., 2015; Dinh and Kleimeier, 2007; Ince and Aktan, 2009; Schreiner, 2004). Credit scoring is supported by computers and thus is fully automated (de Cnudde et al., 2015). At the same time, scoring is able to handle large volumes of loans (Ince and Aktan, 2009).

Due to all its advantages, credit scoring became popular in semi-urban and urban MFIs (e.g. Schreiner, 2004). However, in rural areas where agriculture clients predominate, MFIs are hesitating to adopt credit scoring (Wenner et al., 2007). In this context, (agricultural) scoring models could contribute to improving the risk assessment of rural MFIs. Furthermore, as semi-urban and urban microfinance lenders extend their business to rural areas, their risk assessment should be adapted to granting more loans to agricultural clients, e.g. through specific scoring models. In the past, semi-urban and urban MFIs hesitated to lend to the agricultural sector because it is associated with a higher risk (de Nicola 2015; Weber and Musshoff, 2012). With this in mind, agricultural scoring models could be beneficial for expanding MFIs as well.

One reason why lenders hesitate to lend to agricultural businesses is their exposure to external production factors (de Nicola, 2015). External factors, such as climate condition, are found to influence the creditworthiness of a borrower (Castro and Garcia, 2014). It is predicted that due to a changing climate, the production risk of agriculture is even increasing in the future (Finger and Schmid, 2008). One option to capture weather conditions in a credit scoring model is with the inclusion of precipitation data (Barnett and Mahul, 2007). To the best of our knowledge, the estimation of an agricultural scoring model in general and the inclusion of precipitation in a scoring model in particular are both absent in the microfinance literature.

Therefore, the objective of this paper is to design a specific scoring model for agricultural clients. Furthermore, this paper aims to contribute to the empirical literature of microfinance credit scoring with the comparison of the agriculture and non-agricultural model. In addition, this

[1] Therefore, scoring is applicable to individual but not group lending.

study aims to refine the agricultural scoring model by accounting for precipitation as an external production factor. This analysis is conducted using data from Madagascar, which has an economic and social situation typical for Africa (Minten et al., 2009). MFI and precipitation data is merged and used to estimate loan default by a logistic regression model. Results indicate that microfinance agricultural scoring models predict repayment performance similarly well compared to non-agricultural scoring models. However, the inclusion of precipitation data into the agricultural scoring model does not improve the prediction accuracy.

The remainder of this paper is structured as follows: In the next section, a literature review leading to the research hypotheses is provided. A description of the data set is given in section three. In section four, the model building procedure is presented along with the underlying logistic regression models. This is followed by the results and discussion in section five. Finally, section six contains a conclusion and suggestions for further research.

2. Literature review and hypotheses

Microfinance credit scoring does indeed seem to work well and improve risk management systems. Firstly, scoring increases efficiency of loan assessment (Bumacov et al., 2014). Bumacov et al. (2014) summarized credit scoring as an option to increase the productivity of loan officers in MFIs. In addition, Schreiner (2004) highlighted the advantages of credit scoring models for increasing objectivity and being able to reflect complex causal relationships despite the multiple influences on credit risk. Both de Cnudde et al. (2015) and van Gool et al. (2012) mentioned the advantage of scoring as an automated process which assists the loan officer as a refinement tool in the process of lending decisions. This combination of statistical tools and human best practices diminishes credit risk and loan default (van Gool et al., 2012). The improvement of risk management is eventually reflected in cost reduction (Ince and Aktan, 2009; Schreiner, 2004).

Perhaps these advantages are the reason why scoring seems to become more and more popular in the microfinance sector. In this context, Bumacov et al. (2014) conducted an online survey in which they estimated the prevalence of scoring. Out of 405 MFI´s who participated in their survey, 403 stated that they apply some type of credit scoring, whereas only two MFIs described that they are currently not using scoring due to bad experiences with it. A broad credit scoring literature already exists for developing countries. The geographical coverage of this literature includes Africa (Kammoun and Triki, 2016; Kinda and Achonu, 2012), Asia (Dinh and Kleimeier, 2007), Eastern Europe (van Gool et al., 2012) and Latin America (Blanco et al., 2013; Schreiner, 2004). In all regions, scoring models are found to be suitable to either determine credit risk or support loan officers in decision making (Blanco et al., 2013; Dinh and Kleimeier, 2007; Kammoun and Triki, 2016; Kinda and Achonu, 2012; Schreiner, 2004; van Gool et al., 2012).

However, scoring seems to be less common in the agricultural microfinance sector. Wenner et al. (2007) examined the risk management of 42 MFIs in Latin America that are engaged in agricultural lending, and revealed that only one MFI in their analysis applies a scoring model. Agricultural loans substantially differ from non-agricultural loans in their repayment capacity. Seasonality affects the agricultural sector, especially for plant growers. The time gap between capital investment (seeds, fertilizer, etc.) and revenues (harvesting time) is challenging because it does not fit standard microfinance lending products. To address farmers' needs, some MFIs offer loan products in the form of flexible loans (Field and Pande, 2008). In addition, microfinance credit scoring cannot work as a black box. Hence, for the introduction of a scoring model, an agricultural loan officer requires training on agricultural business cycles as well as scoring itself (Swinnen and Gow, 1999). Perhaps this might be seen as an unnecessary inflation of the already complicated lending process, which has been a criticism of scoring in the past.

However, credit scoring could be a necessary innovation in order to expand microfinance in rural areas (Morvant-Roux, 2011). Outside of the agricultural sector, there is already an increasing interest in applying scoring as a risk-management tool (Bumacov et al., 2014). We argue that credit scoring will be an effective risk-management tool for agricultural loans in the microfinance sector too, given that a sufficiently high prediction accuracy can be achieved. Ultimately, this would be a decision support tool to lower lending costs in rural areas. Therefore, we investigate whether credit scoring models for agricultural loans are able to predict default risk correctly. Our first hypothesis is:

H1 "Equality": The prediction accuracy of microfinance credit scoring models for agricultural loans is as good as for non-agricultural loans.

In the microfinance sector, lending to agricultural and rural clients is perceived as risky (Fernando, 2007). In this context, Weber and Musshoff (2012) investigated whether agricultural lending is indeed more risky than non-agricultural lending. The research was based on the example of a Tanzanian MFI. Weber and Musshoff (2012) showed that agricultural clients do face obstacles in accessing loans, which confirms the initial perception that these clients are riskier. However, Weber and Musshoff (2012) found agricultural loans actually show a better repayment performance than non-agricultural loans. This finding is in line with Baklouti (2014) and van Gool et al. (2012), who both reported a better repayment performance of agricultural loans.

The negative perception of agriculture, however, may originate from its seasonality and external production risk. For a crop farmer with seasonal cash-flows, frequent repayments starting soon after loan disbursement are problematic (Fernando, 2007). This volatility in the business cycle is observed as a threat to repayment (de Nicola, 2015). Additionally, experiencing a low yield or a crop failure can aggravate the situation even further. The underlying reasons for unpredictable agricultural output are external factors such as pests, diseases, and extreme weather like drought and flood. de Nicola (2015) mentions that the risk structure of agricultural businesses is the reason why MFIs are reluctant to lend to them. For instance, Castellani and Cincinelli (2015) emphasized that droughts negatively affect most African MFIs and even put rural MFIs' sustainability at risk. Collier et al. (2011) investigated the effect of the weather event el Niño on loan portfolios, and found that this weather pattern causes repayment trouble and increased loan defaults. Furthermore, de Nicola (2015) found that climatic factors explain variation in loan default. In addition, Castro and Garcia (2014) also found a significant effect of climatic factors on default of agricultural loans. In summary, even though farmers show a good repayment performance, the direct dependence of production on external weather factors leads to the perception that agriculture is riskier than other business.

Additionally, climate change is likely to exacerbate this situation. There is a growing concern about climate change affecting agricultural production (Khandker and Koolwal, 2016). Weather patterns such as heatwaves and heavy precipitation are predicted to become even more volatile and extreme (Coumou and Rahmstorf, 2012). In general, yield levels in Sub-Saharan Africa are expected to fall (Schlenker and Lobell, 2010). In Madagascar in particular, the production of the staple crops maize and rice is predicted to decrease due to climate change (Lobell et al., 2011). In summary, weather patterns can be linked to agricultural loan default, and extreme weather events are likely to increase the rate of default.

Castro and Garcia (2014) emphasized the need of banks to manage common risks to agriculture through quantitative risk management. Dercon (2004) showed that the economic impact of a rainfall shock is long-lasting. This implies that if the weather during the loan maturity has an influence on loan default, it is even possible that weather immediately or moderately before loan disbursement also affects the default risk. In Madagascar, precipitation is found to be a good proxy for weather-induced credit risk, which outperforms other weather measurements such as temperature (Pelka et al., 2015). Hence, we utilize precipitation as an explanatory variable in a scoring model. It is expected that by incorporating weather information, the predictive power of the scoring model increases, while the agricultural production risk covered by the MFI declines. Therefore our second hypothesis is:

H2 "Weather impact": Incorporating weather variables will improve credit scoring for agricultural clients.

3. Data

This study focuses on Madagascar because its situation is typical for other African countries (Minten et al., 2009). In Madagascar, financial services are mainly offered in urban areas, and MFIs started expanding their business to the rural areas only in recent years. Hence, rural areas are still largely unbanked. Furthermore, similar to other African countries, the agricultural sector in Madagascar is the major source of employment and an important contributor to the country's GDP.

Historical records of an operating MFI containing client information is a pre-requirement for any credit scoring model (Bumacov et al., 2014; Mileris and Boguslauskas, 2010). These MFI records can be enriched or linked to further information, such as soft information from social networks (de Cnudde et al., 2015) or mobile phone usage (Björkegren and Grissen, 2015), in order to improve scoring models or to explain underlying mechanisms of repayment behavior. The two underlying data sets used to investigate our hypotheses were provided by the AccessBank Madagascar (ABM) and CelsiusPro. The ABM, a commercial MFI operating in Madagascar, provided us with loan and client data, while CelsiusPro, an insurance company which offers its services globally, provided us with the necessary precipitation data for Madagascar.

The ABM started its business in 2007 in the capital Antananarivo. Currently, their network comprises 19 branches and is reaching into rural and farm-based areas. The ABM offers only individual loans to clients rather than group loans. To enable a comparison, both agricultural loans and non-agricultural loans are used in the analysis. Loan and client information from the ABM were extracted from the management information system and cover the time period of November 2010 to January 2015. However, since client information, i.e. socioeconomic data, is entered manually into the system, data cleaning was necessary. During the data cleaning, obvious errors, e.g. age under 18, and observations with missing values were excluded. Additionally, unfinished loans were excluded from the analysis to achieve consistent and comparable repayment rates. The total number of loans used in the analysis is 24,219, of which 21,831 are non-agricultural and 2,388 are agricultural loans.

Table 1 shows the descriptive statistics of agricultural and non-agricultural loans. It is noteworthy that only 8 of the 19 branches offer agricultural loans. In addition, financial indicators, e.g. applied loan amount, collateral, and income, seem to be lower on average for agricultural clients than for non-agricultural ones. By far, the majority of agricultural investments are put towards crop cultivation rather than livestock production. Furthermore, it is interesting that agricultural clients have greater working experience compared to non-agricultural clients.

Table 1: Descriptive statistics

Variable	Description	Agricultural Mean	Non-Agricultural Mean
Age	Age of applicant in years	43.74	41.34
		(10.59)	(10.14)
Applied loan amount	Applied loan amount in thousands of Malagasy Ariary	1,481	2,683
		(1,543)	(3,181)
Assets	Assets in in thousands of Malagasy Ariary	3,011	5,862
		(3,998)	(19,200)
Branch:			
1	1 if applicant is from branch 1; 0 otherwise		0.06
2	1 if applicant is from branch 2; 0 otherwise		0.15
3	1 if applicant is from branch 3; 0 otherwise		7.41e-03
4	1 if applicant is from branch 4; 0 otherwise		0.07
5	1 if applicant is from branch 5; 0 otherwise		0.01
6	1 if applicant is from branch 6; 0 otherwise		0.08
7	1 if applicant is from branch 7; 0 otherwise	0.02	0.09
8	1 if applicant is from branch 8; 0 otherwise	0.24	0.09
9	1 if applicant is from branch 9; 0 otherwise	0.18	0.04
10	1 if applicant is from branch 10; 0 otherwise	0.22	0.04
11	1 if applicant is from branch 11; 0 otherwise		0.08
12	1 if applicant is from branch 12; 0 otherwise		0.04
13	1 if applicant is from branch 13; 0 otherwise	0.20	0.02
14	1 if applicant is from branch 14; 0 otherwise	2.93e-03	0.04
15	1 if applicant is from branch 15; 0 otherwise		0.04
16	1 if applicant is from branch 16; 0 otherwise		0.03
17	1 if applicant is from branch 17; 0 otherwise	0.14	0.02
18	1 if applicant is from branch 18; 0 otherwise		1.94e-03
19	1 if applicant is from branch 19; 0 otherwise	8.38e-04	4.31e-05
Collateral	Collateral in thousands of Malagasy Ariary	2,945	5,998
		(3,652)	(10,400)
Debt	Debt to other bank in thousands of Malagasy Ariary	57	162
		(294)	(1,194)
Deposit	Deposit in the bank account in thousands of Malagasy Ariary	9	85
		(107)	(1,055)
Disbursed loan amount	Granted loan amount in thousands of Malagasy Ariary	1,061	1,981
		(1,031)	(2,680)
Gender	1 if applicant is female; 0 otherwise	0.26	0.57
Income	Monthly business and household income in thousands of Malagasy Ariary	9,792	51,500
		(20,200)	(131,000)
Marital status:			
single	1 if applicant is single; 0 otherwise	0.05	0.08
married	1 if applicant has a spouse; 0 otherwise	0.91	0.85
divorced	1 if applicant is divorced; 0 otherwise	0.02	0.03
other	1 if marital status is unknown; 0 otherwise	0.03	0.04
No. family members	Number of family members	4.96	3.96
		(1.98)	(1.65)

Table 1: Continued

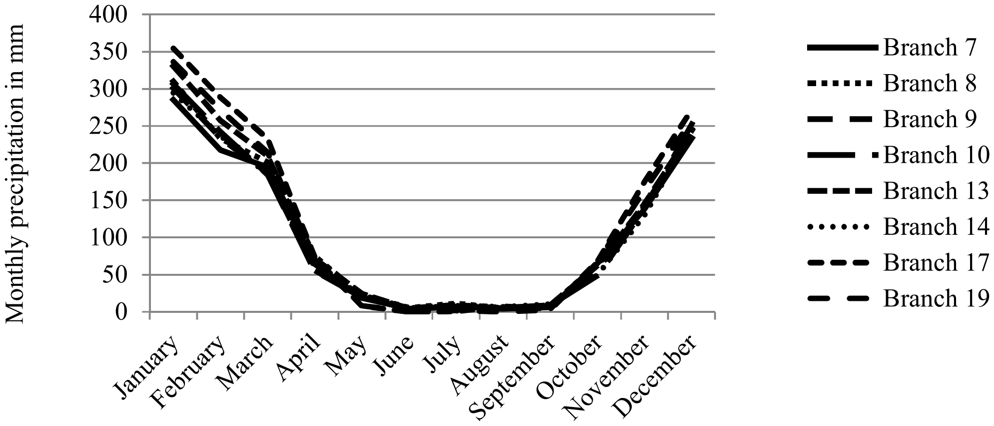
Variable	Description	Agricultural Mean	Non-Agricultural Mean
No. installments	Number of loan installments	11.53	13.23
		(2.31)	(3.95)
Purpose of credit:			
liquidity	1 if loan purpose is liquidity; 0 otherwise	0.87	0.73
investment	1 if loan purpose is investment; 0 otherwise	0.045	0.12
liquidity and investment	1 if loan purpose is liquidity and investment; 0 otherwise	0.08	0.13
others	1 if loan purpose is unknown; 0 otherwise	2.93e-03	0.03
Repayment capacity	Applicants repayment capacity in thousands of Malagasy Ariary	3,545	5,133
		(7,440)	(14,200)
Repeat	1 if applicant had a loan before; 0 otherwise	0.35	0.51
Sector of credit:			
crops	1 if specialized in plant cultivation; 0 otherwise	0.95	
livestock	1 if specialized in animal production; 0 otherwise	0.041	
others	1 if specialization is unknown; 0 otherwise	0.012	
Resident	1 if applicant is a resident; 0 otherwise	0.99	0.99
Working experience	Working experience in current profession in months	16.42	9.90
		(8.66)	(9.90)
Number of observations		2,388	21,831

Notes: For respective variables, standard errors given in parentheses.

Precipitation data is recorded by official weather stations or satellite-based systems. The data set contains daily precipitation which was matched to the location of each agricultural lending branch. Precipitation data was available from the year 1990 until 2015. Figure 1 shows the average annual distribution of precipitation for each branch. On average, precipitation between branches is quite homogenous. The areas can be characterized as having a dry season during May through September and a wet season during October through April.

After merging the MFI data with the precipitation information, it was necessary to divide the data set into two independent subsamples for the purpose of estimating and testing the scoring model properly. The separation of the data set is not random; rather, information is sorted by the disbursement date and then divided into an older and a more recent data set. The first sample, referred to as in-sample data, is used for model building and contains 70% of the loans. The remaining 30%, referred to as out-of-sample data, are then later used for statistically testing the developed scoring models (Tasche, 2005). This procedure reflects a practical application. Under real conditions, the scoring model will always rely on already available (old) data to estimate the risk of a new loan application (Schreiner, 2004).

Figure 1: Precipitation for branches providing agricultural loans



4. Empirical model building

In the literature, there is a great variety of scoring methods. Madhavi and Radhamani (2014) report that support vector machines had the highest accuracy in their study, while Baklouti (2014) advocates a classification and regression tree, which outperforms discriminant analysis and logistic regression. In contrast, Cubiles de la Vega et al. (2013) compared classification trees, ensemble methods, linear and quadratic discriminant analysis, logistic regression, multilayer perceptron, and support vector machines, and found that multilayer perceptron performs the best. This is in line with Blanco et al. (2013), who compared linear and quadratic discriminant analysis, logistic regression and multilayer perceptron. Their results also show that the multilayer perceptron performs the best. However, these results are contradicted by two other studies: Kammoun and Triki (2016) found that logistic regression outperforms multilayer perceptron, and Mileris and Boguslauskas (2010), who compared discriminant analysis, logistic regression, and multilayer perceptron, show that logistic regression outperforms the other two. The impression that model recommendations vary widely is supported by Abdou and Pointon (2011), who reviewed 214 studies on credit scoring and conclude that there is no single best scoring method. However, it seems that logistic regression is the dominant recommendation in the literature, and is also preferable because of its simplicity (Olagunju and Ajiboye, 2010). Therefore, this study also utilizes logistic regression.

The aim of every scoring model is to separate good from bad borrowers (Mileris and Boguslauskas, 2010). Therefore, we need to define a good and a bad borrower. This is usually done using days in arrears for overdue loans; however, the number of days can vary. For instance, a classification of 1, 30 or 90 days in arrears is commonly applied (Pelka et al., 2015). For many banks in developing countries, 1 day in arrears is perceived as signifying a reliable borrower, while 30 days in arrears is already seen as being too costly for the bank. Therefore, as a compromise, the scoring literature in developing countries mostly use 15 days in arrears to define a loan as bad (Baklouti, 2014; Blanco et al., 2013; Cubiles de la Vega et al., 2013; Schreiner, 2004). We follow the literature and adopt the definition of 15 days in arrears for a bad loan.[2]

The selection of the independent variables follows a stepwise selection process, considers expert knowledge commonly used in credit scoring, and is only based on observations from the in-sample data (Hand and Henley, 1997; van Gool et al., 2012). This is done separately for agricultural and non-agricultural loans since some variables, e.g. "Sector of credit: livestock," are only applicable for agricultural loans. The limiting factor for including variables in the selection process is simply their availability (Abdou and Pointon, 2011). We therefore can only consider variables collected by the MFI during the loan application process, which are presented in the descriptive statistics. Additionally, we apply quadratic transformation to variables. For all variables, the receiver operating characteristic (ROC) curve is estimated and variables are ranked in accordance with the area under the curve (AUC), a measurement of classification accuracy (Blanco et al., 2013; van Gool et al., 2012). Only variables which positively affect the AUC and have a p-value below 10 percent are kept in the scoring model. Categorical variables are kept as long as one category fulfills these requirements, while quadratic terms are dismissed if they have a p-value above 10 percent.

Table 2 summarizes the selected variables for the agricultural and non-agricultural models. The majority of selected variables are similar, while the agricultural model utilizes 11 variables versus 10 variables for the non-agricultural model. However, there is no recommendation regarding the optimal number of variables (Abdou and Pointon, 2011). In this context, Abdou and Pointon (2011) report that applied scoring models use about 3 to 20 variables; therefore, our models appear to be typical.

To investigate our second hypothesis, we need to incorporate weather into our agricultural model. As in the literature, we utilize accumulated precipitation data. Possible accumulation periods include single and multiple months (Berg and Schmitz, 2008; Barnett and Mahul, 2007; Pelka et al., 2015). This study relies on the following three types of variables which all use the application date as their reference time: (i) the accumulated rainfall over the last month (e.g. the accumulated rainfall in July when today is in August). Then the time horizon is expanded to include the accumulated rainfall over the last two months and so on, until it considers the total accumulated rainfall over the last 12 months. This produces 12 variables containing accumulated precipitation of 1 month up to 12 months. The idea behind this variable is that rainfall close to the date of loan disbursement may influence the ongoing or future production. (ii) The accumulated

[2] The main results are similar when instead choosing either 30 or 90 days of arrears to define a loan as bad.

rainfall in a specific month, (e.g. precipitation in January, even when today is in August). This is done for each month during the year, resulting in 12 variables containing precipitation of a single month. The idea behind this is that seasonal production cycles may be subject to weather events taking place at a specific time of year. (iii) This variable is similar to (ii), but considers yearly quarters instead of single months (e.g. the accumulated precipitation in the first quarter of the year is considered as a variable even when today is in August). This treatment produces 4 additional variables.

Table 2: Selected variables for the agricultural and non-agricultural models

Variable	Agricultural	Non-agricultural
Age (squared)	yes (no)	yes (yes)
Applied loan amount (squared)	yes (yes)	yes (yes)
Assets (squared)	yes (no)	yes (yes)
Branches[a]	yes	yes
Collateral (squared)	no (no)	yes (yes)
Debt (squared)	yes (no)	yes (yes)
Deposit (squared)	yes (no)	yes (yes)
Gender	yes	no
Marital status	yes	yes
No. of installments	yes	yes
Purpose of credit	no	yes
Sector of credit[b]	yes	no
Working experience (squared)	yes (yes)	no (no)

Notes: [a] branch availability differs, [b] variable is unavailable for non-agricultural clients.

For all three types of variables, quadratic terms are also considered in order to capture non-linear patterns. Furthermore, Barnett and Mahul (2007) describe the effect that extreme weather can have. In our study, extreme weather is defined as events which exceed the 10 year standard deviation of precipitation. Therefore, the 10 year standard deviation for all three types of the aforementioned variables is estimated. Three dummy variables then capture if the precipitation exceeds the standard deviation due to extremely (i) high, (ii) low, or (iii) high and/or low precipitation. In total, 140 different weather variables are considered. The relatively high number of variables assures that no effect remains hidden, but makes a simple presentation in a table difficult. Each variable is then solely tested for increasing the AUC and significance. Expert knowledge is utilized in the final variable selection to include a reoccurring effect of weather patterns on production. Analysis shows that the dry season seems to be a seasonal factor of importance. Therefore, the variable precipitation in the third quarter, which represents this effect best, is used as the weather variable.

Three scoring models were then created. The agricultural model (Model 1) and non-agricultural model (Model 2) are presented in Equation 1 and 2 respectively. Equation 3 presents Model 1 with an extension to include the weather variable, and is referred to as Model 3:

$$Y_i = \beta_0 + \boldsymbol{\beta_1} \boldsymbol{c}_{agro,i} + \boldsymbol{\beta_2} \boldsymbol{l}_{agro,i} + u_i \tag{1}$$

$$Y_i = \beta_0 + \boldsymbol{\beta_1} \boldsymbol{c}_i + \boldsymbol{\beta_2} \boldsymbol{l}_i + u_i \tag{2}$$

$$Y_i = \beta_0 + \boldsymbol{\beta_1} \boldsymbol{c}_{agro,i} + \boldsymbol{\beta_2} \boldsymbol{l}_{agro,i} + \beta_3 w_i + u_i \tag{3}$$

Where Y is a dummy variable that takes the value of 1 for a bad loan and is 0 otherwise for borrower i. The constant is denoted by β_0, while $\boldsymbol{\beta_1}$ and $\boldsymbol{\beta_2}$ represent parameter vectors. The vector of borrower characteristics is represented by $\boldsymbol{c}$, and the vector of loan characteristics is represented by $\boldsymbol{l}$, while the index *agro* indicates the agricultural variable set. β_3 is a parameter for the weather variable indicated by w. The error term is denoted by u. The three estimated scoring models can be found in appendix 1.

Stability is estimated by comparing the in- and out-of-sample AUC values. The more similar the values, the more stable the model, and vice versa (van Gool et al., 2012). The prediction accuracy of a model is indicated by its out-of-sample AUC value. For comparing the prediction accuracy of the three models, a Chi-square test is employed. In addition to the AUC as a measure of model accuracy, some studies also report the misclassification cost of a model. The idea is that type 1 and 2 errors cause different costs to the MFI. Most studies apply a ratio of 1:5 in adherence to the recommendation by West (2000). However, this ratio was designed for German credit data rather than microfinance; thus, the ratio does not take into account losses associated with future loans, and therefore ignores the loan cycle in microfinance (Banerjee et al., 2015; West, 2000). Hence, we solely rely on the AUC as a measure of model accuracy.

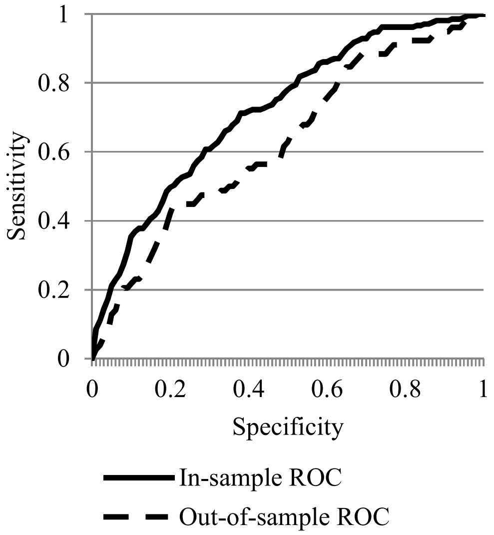
5. Results and discussion

The in- and out-of-sample ROC curves with the respective AUC values are presented for each model in Figure 2. Visually, the ROC curves of Model 2 are smoother than those of Model 1 and 3. This might be due to a higher number of observations, which generally improves the scoring model (Schreiner, 2004). Overall, as expected, the in-sample AUC values always score higher than the out-of-sample AUC values. However, the magnitude of the differences is in the range of those presented in the literature (van Gool et al., 2012). Hence, we evaluate our models as stable. The overall prediction accuracy of our out-of-sample AUC is on the lower end when compared to the literature. However, reported AUC values vary largely across different studies; therefore, reference values are to be considered with caution (e.g. Baklouti, 2014; Blanco et al., 2013; van Gool et al., 2012).

For investigating our H1 "Equality" we compare the out-of-sample performance of Model 1 and Model 2 using a Chi-square test. The result (Chi-square = 0.08, P-value = 0.77) suggests that the AUC of the two models are not significantly different. This shows that microfinance scoring models have similar prediction accuracy for agriculture and non-agricultural clients. Consequently, H1 "Equality" can be accepted.

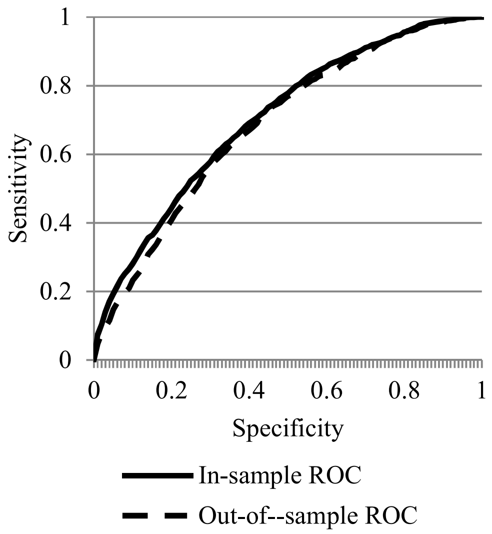
Figure 2: In- and out-of-sample results of the ROC curves and AUC values for Model 1-3

Model 1: agriculture



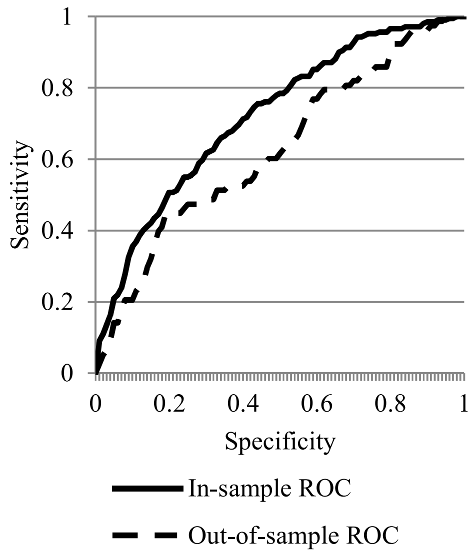
In-sample AUC	0.6992
	(0.0148)
Out-of-sample AUC	0.6494
	(0.0252)

Model 2: non-agriculture



In-sample AUC	0.6924
	(0.0075)
Out-of-sample AUC	0.6570
	(0.0075)

Figure 2: Continued

Model 3: agriculture with precipitation	
	
In-sample AUC	0.7001
	(0.0148)
Out-of-sample AUC	0.6351
	(0.0260)

Notes: For AUC values, standard errors given in parentheses.

This finding implies that, presuming sufficient observations, credit scoring models could also be designed for agricultural clients. Hence, credit scoring can be part of the innovation which is needed to expand microfinance lending into rural areas (Morvant-Roux, 2011). This does not change the fact that agricultural clients still need special lending products to address their seasonal business cycle (Weber et al., 2014).

The visual differences and the lower stability of Model 1 compared to Model 2 might be due to a lower number of observations. Considering the overall loan portfolio of an MFI, agricultural clients are usually a subgroup and consequently their share is smaller. Therefore, these results shows that even under the prevalent circumstances, scoring still works well for the agricultural sector.

For examining H2 "Weather impact" we compare the out-of-sample performance of Model 1 and Model 3 using a Chi-square test. The result (Chi-square = 0.16, P-value = 0.69) suggests that the AUC of the two models are not significantly different. This result implies that the incorporation of an additional weather variable does not increase the performance of the agricultural scoring model. Thus, H2 "Weather impact" can be rejected.

This result shows that the dependency between agricultural production, precipitation, and loan repayment (Pelka et al., 2015), and the long lasting effect of weather events (Dercon, 2004) are insufficient to predict loan repayment in this case. This situation might change over the coming years as yield levels in Sub-Saharan Africa are expected to fall (Schlenker and Lobell, 2010). Furthermore, we cannot rule out the possibility that the incorporation of weather variables into a scoring model might work in a different context or region.

Theoretically, this result could be driven by an unbalanced number of weather events between the in-sample and out-of-sample data sets (e.g. multiple extreme weather events in the in-sample but none in the out-of-sample data set). However, in reviewing the precipitation data, we do not observe such a pattern.

Model 3 has the highest in-sample and lowest out-of-sample AUC. This shows that an additional variable which increases the in-sample AUC does not necessarily have a positive effect on the out-of-sample AUC. Furthermore, this implies that very careful variable selection is required. Schreiner (2004) argues that when a scoring model with few variables works, it should work even better with more variables. This statement seems not to hold true when considering weather variables such as precipitation.

6. Conclusion

Agricultural clients are often associated with posing a higher level of risk to banks. At the same time, credit scoring models, which have been wildly applied by urban MFIs as a risk-assessment tool, are not estimated for agricultural clients specifically. In addition, rural MFIs, which mainly lend to agricultural clients, are hesitating to adopt credit scoring. Therefore, this paper aims to investigate whether credit scoring models can also be applied to agricultural clients. Furthermore, this paper examines whether such agricultural scoring models can be improved by incorporating weather patterns.

For our analysis, we utilize loan and client data provided by the ABM, and precipitation data from CelsiusPro. Data was divided chronologically into an older in-sample and more recent out-of-sample data sets. The in-sample data set was used for model building, while the out-of-sample data set was for testing the models.

The AUC value is applied as a measure of model accuracy. Our results indicate that credit scoring models work equally well for agricultural and non-agricultural clients. This holds true even though the number of observations of agricultural clients was modest compared to the overall loan portfolio. Therefore, this paper supports the implementation of credit scoring models for rural MFIs, presuming a successful test is conducted first. Furthermore, the incorporation of precipitation into the scoring model does not improve its performance in our case. However, we cannot exclude the possibility that weather variables under different circumstances can contribute to credit scoring accuracy in general.

These results are interesting for agricultural lenders as well as for scientists. On the one hand, our study demonstrates the usefulness of credit scoring for agricultural clients. On the other hand, it also shows the current limitations. Further research is therefore necessary to clarify if these findings hold true for different geographical areas and under different climatic conditions. In addition, future research could investigate the effect of extreme weather events like severe droughts and floods. It might also be interesting to research if, rather than precipitation, an evaporation index can contribute to improved model accuracy.

Appendix 1: Estimation results of the logistic regression for 15 days in arrears

Variable	Model 1	Model 2	Model 3
Age	-0.01	0.02	-0.01
	(0.01)	(0.01)	(0.01)
Age squared	-	4.84e-04***	-
		(1.67e-04)	
Applied loan amount	6.19e-7***	2.87e-07***	6.02e-07***
	(1.05e-7)	(2.14e-08)	(1.06e-07)
Applied loan amount squared	-3.86e-14***	-8.84e-15***	-3.80e-14***
	(9.80e-15)	(1.07e-15)	(9.82e-15)
Assets	-1.53e-07***	-1.93e-08***	-1.50e-07***
	(3.87e-08)	(3.37e-09)	(3.87e-08)
Assets squared	-	4.39e-17***	-
		(1.07e-17)	
Branch:			
1	-	-0.73***	-
		(0.21)	
2	-	-0.33*	-
		(0.20)	
3	-	-1.08***	-
		(0.29)	
4	-	-0.21	-
		(0.20)	
5	-	-0.98***	-
		(0.21)	
6	-	-.65***	-
		(0.21)	
7	0.71*	-1.03***	0.64
	(0.43)	(0.21)	(0.43)
8	-0.41	-0.17	-0.47*
	(0.28)	(0.20)	(0.28)
9	-0.19	-0.55***	-0.24
	(0.28)	(0.21)	(0.29)
10	-0.43	-	-0.50*
	(0.28)		(0.29)
Collateral	-	-3.40e-08***	-
		(7.24e-09)	
Collateral squared	-	2.87e-16***	-
		(7.58e-17)	
Debt	8.08e-07**	2.20e-07***	8.11e-07
	(3.17e-07)	(4.45e-08)	(3.19e-07)
Debt squared	-	-1.14e-14***	-
		(3.16e-15)	
Deposit	-1.20e-05	-4.57e-06***	-1.22e-05**
	(7.70e-06)	(6.52e-07)	(7.69e-06)
Deposit squared	-	7.33e-14***	-
		(1.09e-14)	
Gender	0.35**	-	0.35**
	(0.14)		(0.14)

Appendix 1: Continued

Marital status:			
single	-1.00**	-0.17	-1.01**
	(0.45)	(0.12)	(0.45)
married	-1.01***	-0.34***	-1.00***
	(0.34)	(0.10)	(0.34)
divorced	-0.91	0.24*	-0.91
	(0.61)	(0.14)	(0.62)
other	-	-	-
No. installments	0.15***	0.07***	0.15***
	(0.03)	(0.01)	(0.03)
Purpose of credit: liquidity:	-	0.20	-
		(0.14)	
investment	-	0.07	-
		(0.14)	
liquidity and investment	-	0.26*	-
		(0.14)	
others	-	-	-
Sector of credit: animal	-0.68**		-0.69**
	(0.34)		(0.34)
cultivators	-	-	-
others	-0.17		-0.09
	(0.59)		(0.60)
Weather variable	-	-	-0.01*
			(0.01)
Working experience	0.05*	-	0.05*
	(0.03)		(0.03)
Working experience squared	-1.32e-3*	-	1.30e-3*
	(7.51e-4)		(7.45e-4)
Constant	-1.994	-0.644*	-1.88***
	(-1.99)	(0.35)	(0.68)

Notes: *,**,*** indicate a significance level at 10%, 5% and 1% respectively. For all coefficients, standard errors given in parentheses.

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Die Wurzeln der **Fakultät für Agrarwissenschaften** reichen in das 19. Jahrhundert zurück. Mit Ausgang des Wintersemesters 1951/52 wurde sie als siebente Fakultät an der Georgia-Augusta-Universität durch Ausgliederung bereits existierender landwirtschaftlicher Disziplinen aus der Mathematisch-Naturwissenschaftlichen Fakultät etabliert.

1969/70 wurde durch Zusammenschluss mehrerer bis dahin selbständiger Institute das **Institut für Agrarökonomie** gegründet. Im Jahr 2006 wurden das Institut für Agrarökonomie und das Institut für Rurale Entwicklung zum heutigen **Department für Agrarökonomie und Rurale Entwicklung** zusammengeführt.

Das Department für Agrarökonomie und Rurale Entwicklung besteht aus insgesamt neun Lehrstühlen zu den folgenden Themenschwerpunkten:

- Agrarpolitik
- Betriebswirtschaftslehre des Agribusiness
- Internationale Agrarökonomie
- Landwirtschaftliche Betriebslehre
- Landwirtschaftliche Marktlehre
- Marketing für Lebensmittel und Agrarprodukte
- Soziologie Ländlicher Räume
- Umwelt- und Ressourcenökonomik
- Welternährung und rurale Entwicklung

In der Lehre ist das Department für Agrarökonomie und Rurale Entwicklung führend für die Studienrichtung Wirtschafts- und Sozialwissenschaften des Landbaus sowie maßgeblich eingebunden in die Studienrichtungen Agribusiness und Ressourcenmanagement. Das Forschungsspektrum des Departments ist breit gefächert. Schwerpunkte liegen sowohl in der Grundlagenforschung als auch in angewandten Forschungsbereichen. Das Department bildet heute eine schlagkräftige Einheit mit international beachteten Forschungsleistungen.

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